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THERMAL ANALYSIS OF THE ULTRAVIOLET IMAGER CAMERA AND ELECTRONICS

Prepared for

NASA/Marshall Space Flight Center

11 July 1991

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Thermal Analysis of the Ultraviolet Imager Camera and Electronics

3799-TA-01
Rev 0 Chg 0

Prepared by: Gregory J. Dirks

Date: 11 July 1991

Initial Issue: 11 July 1991

Table of Contents

List of Tables

1. Scope

The Ultraviolet Imaging experiment has undergone design changes that necessitate updating the reduced thermal models (RTM's) for both the Camera and Electronics. In addition, there are several mission scenarios that need to be evaluated in terms of thermal response of the instruments. The intent of this report is to assess and document the impact of these design changes and mission scenarios on the thermal performance of the Camera and Electronics assemblies. This report is also responsive to the requirements of NASA/MSFC purchase order number H-10857D, under which the work was performed.

2. Applicable Documents

The documents referenced here contain relevant information necessary for the performance of this thermal analysis.

NASA

Purchase Order No. H-10857D	Ultraviolet Imager Thermal Analysis May 9, 1991
R. Stavely Memorandum	Selected GGS Radiator Surface Thermo-Optical Properties - April 9, 1991

GE/Astro

Program Information Release 89-037	GGS Standard Thermal Analysis Parameters May 15, 1989

Military

MIL-HDBK-5E	Metallic Materials and Elements for Aerospace Vehicle Structures

3. Camera

The UVI Camera thermal performance has been assessed with regards to recent design changes and mission scenarios.

3.1 Design Changes

The design changes to the UVI Camera are mainly material ones that were made in order to reduce weight. The following list details the specific design changes to be considered in evaluating the thermal response of the instrument.

* All structural and housing (including optical bench, radiator and link) elements are magnesium alloy AZ31B-H24.

* The baffle support is aluminum alloy 6061-T6 and the baffle spacer is G-10 fiberglass.

* The piston (cold finger) is aluminum alloy 6061-T6. This is the only element between the radiator link and CCD chip.

* Surface finish for the optical bench is galvanic anodize per MIL-M-3171, Class IV (Dow 9 process). The housing surface finish is obtained using the Dow 23 process.

* The radiator surface is Sumitomo Bakelite FST-8403 (silver deposited poly ether imide - PEI).

3.2 RTM Changes

The design changes listed in section 3.1 necessitated an update to the Camera reduced thermal model (RTM). The following list details the specific changes that were made to the RTM.

* Several conductance and capacitance values changed in order to incorporate the new material propteries. Table 4a of Appendix A lists all conductance values while table 2 shows capacitance values for all elements.

* The required radiator conductance to space (FeA) is .1519 ft^2. In this instance the view factor F is equal to 1.0. Therefore, any combination of emissivity, e, and area, A, that results in .1519 ft^2 is acceptable from a nominal mission point of view. Using PEI as a baseline and assuming a .78 value for emissivity yields an area of 28 in^2.

* The results of this report are based on stacked worst case conditions which includes a +50/-25 percent variation in the nominal MLI effective emissivity. However, only the nominal value of .012 is used for the RTM delivered for integration.

* Two nodes and four conductors have been added to account for the thermal interaction of the exposed radiator links internal to the housing.

* Allowable temperature limits for several elements have been expanded. Table 2 in Appendix A shows the proposed temperature ranges for all elements.

3.3 Results

The revised RTM was run for nominal, extended and pre mission conditions as well as conditions simulating operational heater failure. Table 3.3-1 summarizes the computer runs and the corresponding parameters. Appendix B contains computer listings of all runs which show the temperature profiles for all elements.

Table 3.3-1
Camera RTM Runs

Title	Case	Description			
		Scenario	Case	Condition	Radiator
1. Camera	NM-NH-O-P	Nominal	Nominal Hot	Operating	PEI
2. Camera	NM-WCH-O-P	Nominal	W.C. Hot	Operating	PEI
3. Camera	NM-NC-O-P	Nominal	Nominal Cold	Operating	PEI
4. Camera	NM-WCC-O-P	Nominal	W.C. Cold	Operating	PEI
5. Camera	NM-NH-N-P	Nominal	Nominal Hot	Non-operating	PEI
6. Camera	NM-WCH-N-P	Nominal	W.C. Hot	Non-operating	PEI
7. Camera	NM-NC-N-P	Nominal	Nominal Cold	Non-operating	PEI
8. Camera	NM-WCC-N-P	Nominal	W.C. Cold	Non-operating	PEI
9. Camera	EM-WCH-N-P	Extended	W.C. Hot	Non-operating	PEI
10. Camera	EM-WCH-N-O	Extended	W.C. Hot	Non-operating	OSR
11. Camera	EM-WCH-N-G	Extended	W.C. Hot	Non-operating	Green
12. Camera	PM-WCH-N-P	Pre-	W.C. Hot	Non-operating	PEI
13. Camera	PM-WCH-N-O	Pre-	W.C. Hot	Non-operating	OSR
14. Camera	PM-WCH-N-G	Pre-	W.C. Hot	Non-operating	Green
15. Camera	HF-WCC-O-P	Htr Failure	W.C. Cold	Operating	PEI

3.3.1 Nominal Mission

The nominal mission is subject to sun angles between 90 (hot case) and 160 (cold case) degrees. Also, the instrument may be in either an operational or non-operational mode. For this mission scenario, only, both the nominal and worst case MLI effective emissivities were evaluated. Table 3.3.1-1 summarizes the most important component temperatures.

Table 3.3.1-1
Nominal Mission - Camera

Run No.	Component Temperature (C)			
	Optical Bench	Det. Elect.	CCD Chip	Radiator
1	25.8	30.7	-55.2	-62.1
2	29.7	35.6	-52.6	-59.9
3	20.4	25.2	-61.8	-68.7
4	20.4	24.2	-62.7	-69.3
5	20.2	17.8	-61.4	-66.0
6	22.2	19.9	-60.3	-64.9
7	-19.6	-21.4	-83.3	-86.9
8	-22.6	-24.3	-84.9	-88.4

3.3.2 Extended Mission

The extended mission (5 year) subjects the spacecraft to sun angles between 25 and 90 degrees. All angles less than 90 degrees are during non-operational periods. Therefore, the 25 degree sun angle and non-operating conditions were used to evaluate the thermal response. Another variable included in this mission scenario is radiator surface thermo-optical properties. Computer runs were made for silver deposited poly ether imide (PEI), optical solar relfectors (OSR), and conductive green paint. Table 3.3.2-1 summarizes the important component temperatures.

Table 3.3.2-1
Extended Mission - Camera

Radiator Surface	Component Temperature (C)			
	Optical Bench	Det. Elect.	CCD Chip	Radiator
PEI	29.5	29.2	16.1	15.3
OSR	27.6	26.7	-2.1	-3.8
Green	33.2	33.5	45.9	46.6

3.3.3 Pre Mission

Prior to the nominal mission, during orbit insertion, the spacecraft will see sun angles down to 45 degrees for 2 hours. Again, this will be a non-operational period and the same three radiator surfaces evaluated for the extended mission were evaluated under this condition. Table 3.3.3-1 summarizes the important component temperatures. These temperatures are those present in the instrument at the conclusion of the 2 hour exposure.

Table 3.3.3-1
Pre Mission - Camera

Radiator Surface	Component Temperature (C)			
	Optical Bench	Det. Elect.	CCD Chip	Radiator
PEI	25.7	24.5	-12.4	-17.2
OSR	25.6	24.3	-18.1	-23.8
Green	26.1	25.7	23.1	22.6

3.3.4 Heater Failure

Undetected heater failure for a period of up to 24 hours is another scenario evaluated. This condition would occur during the nominal mission and under operating conditions. Also, it is assumed that only the operational heaters have failed and that the spacecraft provided heaters will be working.

The temperatures of the important components will be as follows: optical bench -13.4 C, detector electronics -9.1 C, CCD chip -76.8 C, and radiator -82.3 C.

4. Electronics

The UVI Electronics thermal performance has been assessed with regards to recent design changes and mission scenarios.

4.1 Design Changes

The two major design changes to the UVI Electronics that will affect the thermal performance of the are listed below.

* The housing (card frames) material has been changed from aluminum alloy to a magnesium alloy AZ31B-H24.

* The radiator surface is baselined using Sumitomo Bakelite FST-8403 (silver deposited poly ether imide - PEI).

4.2 RTM Changes

The design changes mentioned in section 4.1 necessitated an update to the Electronics reduced thermal model (RTM). The following list details teh specific changes that were made to the RTM.

* Several conductance and capacitance value have been changed to reflect the new material properties. Table 4a of Appendix C contains a complete list of all conductances while table 2 lists the capacitance values for all elements.

* The non-operating heater power should be 3 W applied to both the +X and -X surfaces for a total of 6 W.

* The non-operating cold temperature limit for the radiator needs to be decreased to -25 C.

* The required radiator conductance to space (FeA) is .162 ft^2. In this instance the view factor F is equal to 1.0. Therefore, any combination of emissivity, e, and area, A, that results in .162 ft^2 is acceptable from a nominal mission point a view. Using PEI as a baseline and assuming a .78 value for emissivity yields and area of 30 in^2.

4.3 Results

The revised RTM was run for nominal, extended, and pre mission conditions. Table 4.3-1 summarizes the computer runs and the corresponding parameters. Appendix D contains the computer listings of all runs which show the temperature profiles for all elements.

Table 4.3-1
Electronics RTM Runs

Title	Case	Description			
		Scenario	Case	Condition	Radiator
1. Electronics	NM-H-O-P	Nominal	Hot	Operating	PEI
2. Electronics	NM-C-O-P	Nominal	Cold	Operating	PEI
3. Electronics	NM-H-N-P	Nominal	Hot	Non-operating	PEI
4. Electronics	NM-C-N-P	Nominal	Cold	Non-operating	PEI
5. Electronics	EM-H-N-P	Extended	Hot	Non-operating	PEI
6. Electronics	EM-H-N-O	Extended	Hot	Non-operating	OSR
7. Electronics	EM-H-N-G	Extended	Hot	Non-operating	Green
8. Electronics	PM-H-N-P	Pre-	Hot	Non-operating	PEI
9. Electronics	PM-H-N-O	Pre-	Hot	Non-operating	OSR
10. Electronics	PM-H-N-G	Pre-	Hot	Non-operating	Green

4.3.1 Nominal Mission

The nominal mission exposes the spacecraft to sun angles between 90 and 160 degrees. Also, the instrument may be in either an operational or non-operational mode. Table 4.3.1-1 summarizes the most important component temperatures.

Table 4.3.1-1
Nominal Mission - Electronics

Run #	Component Temperature (C)			
	Electronics	Op. Amp.	Pow. Sup.	Radiator
1	43.2	52.0	54.4	27.3
2	-3.3	4.1	6.6	-12.5
3	-5.0	-2.6	-5.4	-9.6
4	-22.0	-21.4	-20.4	-23.1

4.3.2 Extended Mission

The extended mission (5 year) subjects the spacecraft to sun angles between 25 and 90 degrees. All angles less than 90 degrees are during non-operational periods. Therefore, the 25 degree sun angle and non-operating conditions were used to assess the thermal response. Radiator surface thermo-optical properties were also varied in order to evaluate silver deposited poly ether imide (PEI), optical solar reflectors (OSR), and conductive green paint. Table 4.3.2-1 summarizes the important component temperatures.

Table 4.3.2-1
Extended Mission - Electronics

Radiator Surface	Component Temperature (C)			
	Electronics	Op. Amp.	Pow. Sup.	Radiator
PEI	30.9	31.1	30.2	30.5
OSR	19.7	20.6	19.1	18.0
Green	52.4	51.2	51.5	54.5

4.3.3 Pre Mission

Prior to the nominal mission, during orbit insertion, the spacecraft will see sun angles down to 45 degrees for a maximum of 2 hours. This will be a non-operational period and the same three radiator surfaces evaluated for the extended mission will be evaluated under this condition also. Table 4.3.3-1 summarizes the important component temperatures. These temperatures are those present in the instrument at the conclusion of the 2 hour exposure.

Table 4.3.3-1
Pre Mission - Electronics

Radiator Surface	Component Temperature (C)			
	Electronics	Op. Amp.	Pow. Sup.	Radiator
PEI	20.9	20.0	18.3	15.8
OSR	19.9	18.6	16.8	13.9
Green	29.1	30.8	30.1	31.2

5. Conclusions and Recommendations

The following conclusions and recommendations for the Camera and Electronics are based on the results presented previously in this report and on observations noted during the RTM revision process.

5.1 Camera

The list below details the conclusions and recommendations for the UVI Camera.

* No thermally isolating spacers are needed between the optical bench and baseplate due to the decreased conductivity of the magnesium structure.

* The radiator should be magnesium with an exposed surface of Sumitomo Bakelite FST-8403. The thermo-optical properties of this material would require 28 square inches of clear radiating area (e=.78).

* Variation of the effective MLI emissivity will affect the thermal performance of the instrument especially in the hot case where the emissivity is lowered. However, a +50/-25 percent variation (which is consistent with measured values documented in the referenced GE information release) is possible within the temperature limits specified in this report.

* The heater failure, extended and pre mission scenarios do not represent any survivability problem. Although in the case of heater failure some elements will exceed the operational temperature limits (most notably the optical bench).

5.2 Electronics

The list below details the conclusions and recommendations for the UVI Electronics.

* The radiator surface material should be Sumitomo Bakelite FST-8403. The thermo-optical properties of this material will require 30 square inches of exposed area. This surface finish was selected for two reasons. The main reason is that with an emissivity of .78 it will maximize the exposed surface area which will result in a more uniform temperature distrubution. A secondary consideration is that this will provide commonality with the camera as far as procurement and installation.

* Extended and pre mission conditions do not represent survivability hazard.

Appendix A

Camera RTM

TABLE 1 Node Description		
Number	Description	Location
5200	Baseplate	-Z
5201	Outboard MLI	+Y
5202	Zenith MLI	-X
5203	Inboard MLI	-Y
5204	Angle MLI	+X -Y
5205	Baffle	+X
5206	Nadir MLI	+X
5207	Top MLI	+Z
5208	Radiator	+Z
5209	Outboard Panel	+Y
5210	Zenith Panel	-X
5211	Inboard Panel	-Y
5212	Angle Panel	+X -Y
5213	Nadir Panel	+X
5214	Top Panel	+Z
5215	Optical Bench	Internal
5216	Detector Case	Internal
5217	Detector Elec.	Internal
5218	CCD Chip	Internal
5219	Radiator Link 1	Internal
5220	Radiator Link 2	Internal

TABLE 2
Node Data

Node Number	Capacitance (W-hr/C)	Temperature Limits (C)			
		Operating		Non-Operating	
		Cold	Hot	Cold	Hot
5200	.243	0	40	-20	40
5201	.0527	-180	120	-180	120
5202	.0527	-180	120	-180	120
5203	.0527	-180	120	-180	120
5204	.0527	-180	120	-180	120
5205	.046	-15	90	-40	100
5206	.0527	-180	120	-180	120
5207	.0527	-180	120	-180	120
5208	.032	-80	-50	-100	30
5209	.053	0	40	-20	40
5210	.410	0	40	-20	40
5211	.024	0	40	-20	40
5212	.032	0	40	-20	40
5213	.016	0	40	-20	40
5214	.061	0	40	-20	40
5215	1.02	20	30	-25	40
5216	.300	0	40	-25	40
5217	.020	0	40	-25	40
5218	.020	-65	-50	-100	30
5219	.010	-75	-50	-100	30
5220	.010	-75	-50	-100	30

TABLE 3
Power Data

Node Number	Electrical Power (W)			Heater Power (W)	
	Operating		Non-Operating		
	Hot	Cold	Cold	Operating	Non-Operating
5200	0.0	0.0	0.0	0.0	9.0
5215	1.0	1.0	0.0	10.0	0.0
5217	1.1	1.1	0.0	0.0	0.0
5218	0.1	0.1	0.0	0.0	0.0

Heater Power Application Logic

For the non-operating condition, 9.0 W are to be applied to node 5200 whenever that node temperature is less than -10.0 C and turned off at 0.0

For the operating condition, 10.0 W are to be applied to node 5215 whenever that node temperature is less than 20.0 C and turned off at 25.0 C.

Electrical Power

A $\pm$15 percent tolerance is imposed on electrical power application in the RTM.

TABLE 4a
Linear Conductor Data

Conductor Number	Coupled Nodes		Conductor Value (W/C)
	i	j	
52000	5200	4999	.200
52001	5200	5210	.078
52002	5200	5211	.060
52003	5200	5212	.065
52004	5200	5213	.030
52005	5200	5209	.112
52006	5200	5215	.180
52007	5210	5211	.016
52008	5211	5212	.018
52009	5212	5213	.010
52010	5209	5213	.015
52011	5209	5210	.012
52012	5210	5214	.078
52013	5211	5214	.060
52014	5212	5214	.065
52015	5213	5214	.030
52016	5209	5214	.112
52017	5205	5215	.080
52018	5215	5220	.005
52034	5215	5216	1.00
52043	5216	5217	.176
52044	5216	5218	.002
52045	5217	5218	.004
52046	5218	5219	.117
52048	5208	5219	.100
52049	5208	5220	.100

TABLE 4b
Radiation Conductor Data

Conductor Number	Coupled Nodes		Conductor Value (ft^2)
	i	j	
52019	5207	5214	.0180
52020	5203	5211	.0080
52021	5204	5212	.0091
52022	5206	5213	.0049
52023	5201	5209	.0149
52024	5202	5210	.0120
52025	5202	9999	.414
52026	5207	9999	1.014
52027	5203	8888	.243
52028	5204	8888	.353
52029	5206	9999	.213
52030	5201	9999	.556
52031	5205	9999	.044
52032	5208	9999	.1519
52033	5207	5208	.0568
52035	5200	8888	.008
52036	5200	9999	.005
52037	5201	8888	.296
52038	5202	8888	.251
52039	5203	9999	.207
52040	5204	9999	.201
52041	5205	8888	.013
52042	5206	8888	.069
52047	5214	5215	.6760
52050	5209	5219	.0132
52051	5210	5220	.0132

TABLE 5
Radiation Surface Data

Surface Number	Surface Finish	Optical Properties		
		Solar Absorptivity		
		BOM	EOM	Emissivity
5200	Dow 23	.62	.62	.32
5201	MLI	.40	.52	.72
5202	MLI	.40	.52	.72
5203	MLI	.40	.52	.72
5204	MLI	.40	.52	.72
5205	Black Paint	1.00	1.00	1.00
5206	MLI	.40	.52	.72
5207	MLI	.40	.52	.72
5208	FST 8403	.16	.30	.78

TABLE 6 SMM-TMM Nodal Correspondence	
Thermal Number	Surface Number
5200	5200
5201	5201
5202	5202
5203	5203
5204	5204
5205	5205
5206	5206
5207	5207
5208	5208

Appendix B

Camera Results

Title	Case	Description			
		Scenario	Case	Condition	Radiator
1. Camera	NM-NH-O-P	Nominal	Nominal Hot	Operating	---
2. Camera	NM-WCH-O-P	Nominal	W.C. Hot	Operating	---
3. Camera	NM-NC-O-P	Nominal	Nominal Cold	Operating	---
4. Camera	NM-WCC-O-P	Nominal	W.C. Cold	Operating	---
5. Camera	NM-NH-N-P	Nominal	Nominal Hot	Non-operating	---
6. Camera	NM-WCH-N-P	Nominal	W.C. Hot	Non-operating	---
7. Camera	NM-NC-N-P	Nominal	Nominal Cold	Non-operating	---
8. Camera	NM-WCC-N-P	Nominal	W.C. Cold	Non-operating	---
9. Camera	EM-WCH-N-P	Extended	W.C. Hot	Non-operating	PEI
10. Camera	EM-WCH-N-O	Extended	W.C. Hot	Non-operating	OSR
11. Camera	EM-WCH-N-G	Extended	W.C. Hot	Non-operating	Green
12. Camera	PM-WCH-N-P	Pre-	W.C. Hot	Non-operating	PEI
13. Camera	PM-WCH-N-O	Pre-	W.C. Hot	Non-operating	OSR
14. Camera	PM-WCH-N-G	Pre-	W.C. Hot	Non-operating	Green
15. Camera	HF-WCC-O-P	Htr Failure	W.C. Cold	Operating	---

---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 10:54

Steady State Matrix Routine

1. Camera
NM-NH-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = 9.155E-05 (C) ON NODE 5218
MAXIMUM NODAL ENERGY BALANCE = 4.413E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = 3.090E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	23.336	Arith.	
5201	-84.966	Arith.	2.750E+00
5202	-100.183	Arith.	7.000E-01
5203	-71.532	Arith.	1.700E+00
5204	-44.425	Arith.	4.900E+00
5205	35.533	Arith.	3.400E+00
5206	6.702	Arith.	8.500E+00
5207	-149.808	Arith.	1.000E-01
5208	-70.139	Arith.	2.500E-02
5209	18.938	Arith.	
5210	18.025	Arith.	
5211	20.325	Arith.	
5212	20.817	Arith.	
5213	21.302	Arith.	
5214	21.821	Arith.	
5215	25.807	Arith.	1.000E+00
5216	26.400	Arith.	
5217	30.697	Arith.	1.100E+00
5218	-55.235	Arith.	1.000E-01
5219	-60.423	Arith.	
5220	-62.115	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	30.000	Bndry.	

****

---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

---

---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:19

Steady State Matrix Routine

2. Camera
NM-WCH-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = 9.155E-05 (C) ON NODE 5215
MAXIMUM NODAL ENERGY BALANCE = -4.816E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = -4.725E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	26.062	Arith.	
5201	-85.766	Arith.	2.750E+00
5202	-101.301	Arith.	7.000E-01
5203	-72.149	Arith.	1.700E+00
5204	-44.725	Arith.	4.900E+00
5205	38.234	Arith.	3.400E+00
5206	6.688	Arith.	8.500E+00
5207	-152.811	Arith.	1.000E-01
5208	-68.254	Arith.	2.500E-02
5209	22.679	Arith.	
5210	21.819	Arith.	
5211	24.129	Arith.	
5212	24.551	Arith.	
5213	24.835	Arith.	
5214	25.930	Arith.	
5215	29.718	Arith.	1.150E+00
5216	30.463	Arith.	
5217	35.644	Arith.	1.265E+00
5218	-52.642	Arith.	1.150E-01
5219	-58.064	Arith.	
5220	-59.935	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	30.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:22

Steady State Matrix Routine

3. Camera
NM-NC-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.221E-04 (C) ON NODE 5215
MAXIMUM NODAL ENERGY BALANCE = 2.287E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = 3.060E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	.221	Arith.	
5201	-152.659	Arith.	1.500E-01
5202	-149.280	Arith.	1.750E-01
5203	-150.762	Arith.	1.000E-03
5204	-144.825	Arith.	1.000E-01
5205	-.253	Arith.	1.000E-03
5206	-142.752	Arith.	2.000E-01
5207	-156.301	Arith.	1.000E-03
5208	-75.904	Arith.	
5209	2.210	Arith.	
5210	1.619	Arith.	
5211	3.210	Arith.	
5212	3.294	Arith.	
5213	2.875	Arith.	
5214	10.533	Arith.	
5215	20.364	Arith.	8.500E+00
5216	20.950	Arith.	
5217	25.223	Arith.	1.100E+00
5218	-61.777	Arith.	1.000E-01
5219	-67.020	Arith.	
5220	-68.696	Arith.	
8888	-150.000	Bndry.	
9999	-273.150	Bndry.	
4999	-20.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:26

Steady State Matrix Routine

4. Camera
NM-WCC-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = 1.831E-04 (C) ON NODE 5214
MAXIMUM NODAL ENERGY BALANCE = -2.362E-05 (W) ON NODE 5216
MAXIMUM SYSTEM ENERGY BALANCE = -2.235E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	-.761	Arith.	
5201	-146.922	Arith.	1.500E-01
5202	-143.922	Arith.	1.750E-01
5203	-145.158	Arith.	1.000E-03
5204	-140.344	Arith.	1.000E-01
5205	-.211	Arith.	1.000E-03
5206	-138.161	Arith.	2.000E-01
5207	-149.483	Arith.	1.000E-03
5208	-76.420	Arith.	
5209	.152	Arith.	
5210	-.501	Arith.	
5211	1.108	Arith.	
5212	1.166	Arith.	
5213	.654	Arith.	
5214	9.065	Arith.	
5215	20.419	Arith.	9.350E+00
5216	20.840	Arith.	
5217	24.178	Arith.	9.350E-01
5218	-62.656	Arith.	8.500E-02
5219	-67.778	Arith.	
5220	-69.287	Arith.	
8888	-150.000	Bndry.	
9999	-273.150	Bndry.	
4999	-20.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:28

Steady State Matrix Routine

5. Camera
NM-NH-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = 1.221E-04 (C) ON NODE 5217
MAXIMUM NODAL ENERGY BALANCE = -4.759E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = -3.182E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	24.007	Arith.	
5201	-85.058	Arith.	2.750E+00
5202	-100.303	Arith.	7.000E-01
5203	-71.608	Arith.	1.700E+00
5204	-44.473	Arith.	4.900E+00
5205	31.594	Arith.	3.400E+00
5206	6.673	Arith.	8.500E+00
5207	-151.512	Arith.	1.000E-01
5208	-73.960	Arith.	2.500E-02
5209	17.501	Arith.	
5210	16.604	Arith.	
5211	18.902	Arith.	
5212	19.395	Arith.	
5213	19.884	Arith.	
5214	18.203	Arith.	
5215	20.161	Arith.	
5216	19.682	Arith.	
5217	17.880	Arith.	
5218	-61.394	Arith.	
5219	-65.490	Arith.	
5220	-66.021	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:30

Steady State Matrix Routine

6. Camera
NM-WCH-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.373E-04 (C) ON NODE 5219
MAXIMUM NODAL ENERGY BALANCE = -1.991E-05 (W) ON NODE 5216
MAXIMUM SYSTEM ENERGY BALANCE = -2.565E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	25.660	Arith.	
5201	-85.905	Arith.	2.750E+00
5202	-101.483	Arith.	7.000E-01
5203	-72.264	Arith.	1.700E+00
5204	-44.797	Arith.	4.900E+00
5205	33.037	Arith.	3.400E+00
5206	6.645	Arith.	8.500E+00
5207	-155.055	Arith.	1.000E-01
5208	-73.061	Arith.	2.500E-02
5209	19.937	Arith.	
5210	19.105	Arith.	
5211	21.379	Arith.	
5212	21.800	Arith.	
5213	22.096	Arith.	
5214	20.674	Arith.	
5215	22.222	Arith.	
5216	21.737	Arith.	
5217	19.915	Arith.	
5218	-60.252	Arith.	
5219	-64.395	Arith.	
5220	-64.928	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:31

Steady State Matrix Routine

7. Camera
NM-NC-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.129E-03 (C) ON NODE 5207
MAXIMUM NODAL ENERGY BALANCE = -2.541E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = -2.834E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	-11.179	Arith.	7.650E+00
5201	-156.466	Arith.	1.500E-01
5202	-152.810	Arith.	1.750E-01
5203	-154.504	Arith.	1.000E-03
5204	-147.765	Arith.	1.000E-01
5205	-32.085	Arith.	1.000E-03
5206	-145.785	Arith.	2.000E-01
5207	-167.366	Arith.	1.000E-03
5208	-92.388	Arith.	
5209	-17.373	Arith.	
5210	-17.817	Arith.	
5211	-16.591	Arith.	
5212	-16.520	Arith.	
5213	-16.837	Arith.	
5214	-18.797	Arith.	
5215	-19.613	Arith.	
5216	-19.988	Arith.	
5217	-21.395	Arith.	
5218	-83.309	Arith.	
5219	-86.508	Arith.	
5220	-86.900	Arith.	
8888	-150.000	Bndry.	
9999	-273.150	Bndry.	
4999	-30.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 11:33

Steady State Matrix Routine

8. Camera
NM-WCC-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -2.594E-04 (C) ON NODE 5207
MAXIMUM NODAL ENERGY BALANCE = -1.029E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = -2.452E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	-13.607	Arith.	7.650E+00
5201	-152.133	Arith.	1.500E-01
5202	-148.803	Arith.	1.750E-01
5203	-150.301	Arith.	1.000E-03
5204	-144.506	Arith.	1.000E-01
5205	-34.537	Arith.	1.000E-03
5206	-142.440	Arith.	2.000E-01
5207	-162.265	Arith.	1.000E-03
5208	-93.720	Arith.	
5209	-20.923	Arith.	
5210	-21.400	Arith.	
5211	-20.193	Arith.	
5212	-20.140	Arith.	
5213	-20.516	Arith.	
5214	-22.400	Arith.	
5215	-22.574	Arith.	
5216	-22.940	Arith.	
5217	-24.317	Arith.	
5218	-84.922	Arith.	
5219	-88.053	Arith.	
5220	-88.438	Arith.	
8888	-150.000	Bndry.	
9999	-273.150	Bndry.	
4999	-30.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 14:22

Steady State Matrix Routine

9. Camera
EM-WCH-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 6 ***

MAX. ARITH. NODE TEMP. CHANGE = -3.204E-04 (C) ON NODE 5207
MAXIMUM NODAL ENERGY BALANCE = -1.801E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = -3.780E-07 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	30.586	Arith.	
5201	-85.540	Arith.	2.750E+00
5202	-100.974	Arith.	7.000E-01
5203	-72.009	Arith.	1.700E+00
5204	-44.641	Arith.	4.900E+00
5205	38.110	Arith.	3.400E+00
5206	6.740	Arith.	8.500E+00
5207	-125.480	Arith.	1.000E-01
5208	13.777	Arith.	7.000E+00
5209	26.999	Arith.	
5210	26.563	Arith.	
5211	27.355	Arith.	
5212	27.635	Arith.	
5213	28.097	Arith.	
5214	27.686	Arith.	
5215	29.537	Arith.	
5216	29.457	Arith.	
5217	29.160	Arith.	
5218	16.070	Arith.	
5219	15.394	Arith.	
5220	15.289	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 14:28

Steady State Matrix Routine

10. Camera
EM-WCH-N-O

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 6 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.648E-03 (C) ON NODE 5207
MAXIMUM NODAL ENERGY BALANCE = 3.096E-05 (W) ON NODE 5214
MAXIMUM SYSTEM ENERGY BALANCE = 1.988E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	29.214	Arith.	
5201	-85.648	Arith.	2.750E+00
5202	-101.125	Arith.	7.000E-01
5203	-72.082	Arith.	1.700E+00
5204	-44.685	Arith.	4.900E+00
5205	36.754	Arith.	3.400E+00
5206	6.713	Arith.	8.500E+00
5207	-133.542	Arith.	1.000E-01
5208	-7.150	Arith.	4.700E+00
5209	24.973	Arith.	
5210	24.403	Arith.	
5211	25.691	Arith.	
5212	26.018	Arith.	
5213	26.423	Arith.	
5214	25.750	Arith.	
5215	27.572	Arith.	
5216	27.398	Arith.	
5217	26.742	Arith.	
5218	-2.092	Arith.	
5219	-3.582	Arith.	
5220	-3.788	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 14:32

Steady State Matrix Routine

11. Camera
EM-WCH-N-G

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 6 ***

MAX. ARITH. NODE TEMP. CHANGE = 1.221E-04 (C) ON NODE 5208
MAXIMUM NODAL ENERGY BALANCE = 1.991E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = 3.177E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	33.187	Arith.	
5201	-85.327	Arith.	2.750E+00
5202	-100.671	Arith.	7.000E-01
5203	-71.869	Arith.	1.700E+00
5204	-44.556	Arith.	4.900E+00
5205	40.595	Arith.	3.400E+00
5206	6.793	Arith.	8.500E+00
5207	-111.201	Arith.	1.000E-01
5208	48.658	Arith.	1.200E+01
5209	30.934	Arith.	
5210	30.786	Arith.	
5211	30.512	Arith.	
5212	30.691	Arith.	
5213	31.275	Arith.	
5214	31.332	Arith.	
5215	33.161	Arith.	
5216	33.236	Arith.	
5217	33.518	Arith.	
5218	45.940	Arith.	
5219	46.582	Arith.	
5220	46.642	Arith.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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12. Camera
PM-WCH-N-P

*** CURRENT TIME = 7.2000E+03 (sec) ***

LOOP NO. = 4 LAST TIME STEP = 3.0000E+02 (sec)
MAX. DIFFN. NODE TEMP. CHANGE = 3.204E-03 (C) ON NODE 5219
MINIMUM NETWORK STABILITY = 1.6158E+02 (sec) ON NODE 5219

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5201	-85.154	Diffn.	2.750E+00
5202	-97.567	Diffn.	7.000E-01
5203	-69.361	Diffn.	1.700E+00
5204	-44.506	Diffn.	4.900E+00
5205	35.283	Diffn.	3.400E+00
5206	6.802	Diffn.	8.500E+00
5207	-131.439	Diffn.	1.000E-01
5208	-22.271	Diffn.	2.900E+00
5209	23.626	Diffn.	
5210	23.894	Diffn.	
5211	24.576	Diffn.	
5212	24.816	Diffn.	
5213	25.199	Diffn.	
5214	24.232	Diffn.	
5215	25.651	Diffn.	
5216	25.373	Diffn.	
5217	24.533	Diffn.	
5218	-12.403	Diffn.	
5219	-15.576	Diffn.	
5220	-17.192	Diffn.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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12. Camera
PM-WCH-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. DIFFN. NODE TEMP. CHANGE = -1.831E-04 (C) ON NODE 5215

MAXIMUM NODAL ENERGY BALANCE = 2.513E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = -1.193E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	28.014	Diffn.	
5201	-85.738	Diffn.	2.750E+00
5202	-101.251	Diffn.	7.000E-01
5203	-72.144	Diffn.	1.700E+00
5204	-44.723	Diffn.	4.900E+00
5205	35.536	Diffn.	3.400E+00
5206	6.690	Diffn.	8.500E+00
5207	-140.833	Diffn.	1.000E-01
5208	-27.308	Diffn.	2.900E+00
5209	23.233	Diffn.	
5210	22.559	Diffn.	
5211	24.234	Diffn.	
5212	24.598	Diffn.	
5213	24.959	Diffn.	
5214	24.046	Diffn.	
5215	25.811	Diffn.	
5216	25.544	Diffn.	
5217	24.537	Diffn.	
5218	-19.738	Diffn.	
5219	-22.025	Diffn.	
5220	-22.330	Diffn.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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13. Camera
PM-WCH-N-O

*** CURRENT TIME = 7.2000E+03 (sec) ***

LOOP NO. = 4 LAST TIME STEP = 3.0000E+02 (sec)
MAX. DIFFN. NODE TEMP. CHANGE = 3.860E-03 (C) ON NODE 5219
MINIMUM NETWORK STABILITY = 1.6171E+02 (sec) ON NODE 5219

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	28.191	Diffn.	
5201	-85.160	Diffn.	2.750E+00
5202	-97.570	Diffn.	7.000E-01
5203	-69.363	Diffn.	1.700E+00
5204	-44.507	Diffn.	4.900E+00
5205	35.257	Diffn.	3.400E+00
5206	6.801	Diffn.	8.500E+00
5207	-132.976	Diffn.	1.000E-01
5208	-29.604	Diffn.	2.200E+00
5209	23.475	Diffn.	
5210	23.813	Diffn.	
5211	24.527	Diffn.	
5212	24.770	Diffn.	
5213	25.138	Diffn.	
5214	24.163	Diffn.	
5215	25.595	Diffn.	
5216	25.302	Diffn.	
5217	24.346	Diffn.	
5218	-18.139	Diffn.	
5219	-21.856	Diffn.	
5220	-23.787	Diffn.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

****

13. Camera
PM-WCH-N-O

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. DIFFN. NODE TEMP. CHANGE = 2.441E-04 (C) ON NODE 5215

MAXIMUM NODAL ENERGY BALANCE = -2.480E-05 (W) ON NODE 5216
MAXIMUM SYSTEM ENERGY BALANCE = 8.487E-06 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	27.503	Diffn.	
5201	-85.775	Diffn.	2.750E+00
5202	-101.303	Diffn.	7.000E-01
5203	-72.170	Diffn.	1.700E+00
5204	-44.739	Diffn.	4.900E+00
5205	35.007	Diffn.	3.400E+00
5206	6.680	Diffn.	8.500E+00
5207	-143.966	Diffn.	1.000E-01
5208	-36.477	Diffn.	2.200E+00
5209	22.504	Diffn.	
5210	21.790	Diffn.	
5211	23.614	Diffn.	
5212	23.992	Diffn.	
5213	24.337	Diffn.	
5214	23.318	Diffn.	
5215	25.050	Diffn.	
5216	24.739	Diffn.	
5217	23.571	Diffn.	
5218	-27.809	Diffn.	
5219	-30.464	Diffn.	
5220	-30.814	Diffn.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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14. Camera
PM-WCH-N-G

*** CURRENT TIME = 7.2000E+03 (sec) ***

LOOP NO. = 2 LAST TIME STEP = 3.0000E+02 (sec)
MAX. DIFFN. NODE TEMP. CHANGE = -8.270E-03 (C) ON NODE 5218
MINIMUM NETWORK STABILITY = 1.6062E+02 (sec) ON NODE 5219

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	28.612	Diffn.	
5201	-85.102	Diffn.	2.750E+00
5202	-97.537	Diffn.	7.000E-01
5203	-69.351	Diffn.	1.700E+00
5204	-44.498	Diffn.	4.900E+00
5205	35.482	Diffn.	3.400E+00
5206	6.808	Diffn.	8.500E+00
5207	-119.597	Diffn.	1.000E-01
5208	22.236	Diffn.	8.100E+00
5209	24.865	Diffn.	
5210	24.644	Diffn.	
5211	25.009	Diffn.	
5212	25.216	Diffn.	
5213	25.723	Diffn.	
5214	24.790	Diffn.	
5215	26.051	Diffn.	
5216	25.864	Diffn.	
5217	25.745	Diffn.	
5218	23.051	Diffn.	
5219	22.776	Diffn.	
5220	22.605	Diffn.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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14. Camera
PM-WCH-N-G

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 6 ***

MAX. DIFFN. NODE TEMP. CHANGE = -2.167E-03 (C) ON NODE 5207

MAXIMUM NODAL ENERGY BALANCE = 3.190E-05 (W) ON NODE 5216
MAXIMUM SYSTEM ENERGY BALANCE = 5.171E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	31.195	Diffn.	
5201	-85.492	Diffn.	2.750E+00
5202	-100.905	Diffn.	7.000E-01
5203	-71.977	Diffn.	1.700E+00
5204	-44.621	Diffn.	4.900E+00
5205	38.701	Diffn.	3.400E+00
5206	6.753	Diffn.	8.500E+00
5207	-122.011	Diffn.	1.000E-01
5208	22.465	Diffn.	8.100E+00
5209	27.911	Diffn.	
5210	27.539	Diffn.	
5211	28.095	Diffn.	
5212	28.352	Diffn.	
5213	28.841	Diffn.	
5214	28.543	Diffn.	
5215	30.397	Diffn.	
5216	30.356	Diffn.	
5217	30.205	Diffn.	
5218	23.559	Diffn.	
5219	23.216	Diffn.	
5220	23.152	Diffn.	
8888	-75.000	Bndry.	
9999	-273.150	Bndry.	
4999	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-08-91
Time: 14:48

Steady State Matrix Routine

15. Camera
HF-WCC-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.907E-04 (C) ON NODE 5207
MAXIMUM NODAL ENERGY BALANCE = 3.514E-05 (W) ON NODE 5215
MAXIMUM SYSTEM ENERGY BALANCE = 5.117E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5200	-9.912	Arith.	5.000E+00
5201	-150.969	Arith.	1.500E-01
5202	-147.717	Arith.	1.750E-01
5203	-149.160	Arith.	1.000E-03
5204	-143.592	Arith.	1.000E-01
5205	-27.003	Arith.	1.000E-03
5206	-141.499	Arith.	2.000E-01
5207	-159.096	Arith.	1.000E-03
5208	-87.820	Arith.	
5209	-15.998	Arith.	
5210	-16.513	Arith.	
5211	-15.236	Arith.	
5212	-15.183	Arith.	
5213	-15.585	Arith.	
5214	-15.823	Arith.	
5215	-13.428	Arith.	8.500E-01
5216	-12.892	Arith.	
5217	-9.116	Arith.	9.350E-01
5218	-76.760	Arith.	8.500E-02
5219	-80.891	Arith.	
5220	-82.279	Arith.	
8888	-150.000	Bndry.	
9999	-273.150	Bndry.	
4999	-20.000	Bndry.	

****

Appendix C

Electronics RTM

TABLE 1
Node Description

Number	Description	Location
5250	MLI	+X
5251	Housing	-X
5252	MLI	-X
5253	Housing	+Y
5254	MLI	+Y
5255	MLI	-Y
5256	Housing	-Y
5257	Radiator	+Z
5258	Power Supply	Internal
5259	Baseplate	-Z
5260	Electronics	Internal
5261	Housing	+X
5262	MLI	+Z
5263	Power Op. Amp.	Internal

TABLE 2
Node Data

Node Number	Capacitance (W-hr/C)	Temperature Limits (C)			
		Operating		Non-Operating	
		Cold	Hot	Cold	Hot
5250	.0527	-180	120	-180	120
5251	.0688	-15	40	-25	40
5252	.0527	-180	120	-180	120
5253	.0295	-15	40	-25	40
5254	.0527	-180	120	-180	120
5255	.0527	-180	120	-180	120
5256	.0490	-15	40	-25	40
5257	.0767	-15	30	-25	40
5258	.0100	0	85	-55	125
5259	.0767	-15	40	-25	40
5260	.3420	0	50	-25	40
5261	.0688	-15	40	-25	40
5262	.0527	-180	120	-180	120
5263	.0100	0	85	-55	125

TABLE 3
Power Data

Node Number	Electrical Power (W)			Heater Power (W)	
	Operating		Non-Operating		
	Hot	Cold	Cold	Operating	Non-Operating
5251	0.0	0.0	0.0	0.0	3.0
5258	2.8	2.8	0.0	0.0	0.0
5260	3.4	2.8	0.0	0.0	0.0
5261	0.0	0.0	0.0	0.0	3.0
5263	1.5	1.5	0.0	0.0	0.0

Heater Power Application Logic

For the non-operating condition, 3.0 W are to be applied to nodes 5251 and 5261 whenever these node temperatures are less than -10.0 C and turned off at 0.0

Electrical Power

A $\pm$15 percent tolerance is imposed on electrical power application in the RTM.

TABLE 4a
Linear Conductor Data

Conductor Number	Coupled Nodes		Conductor Value (W/C)
	i	j	
52131	5253	5261	.1360
52132	5253	5251	.1360
52133	5257	5261	.2714
52134	5259	5261	.2714
52135	5257	5251	.2714
52136	5259	5251	.2714
52137	5257	5253	.1240
52138	5253	5258	.1861
52139	5259	5253	.1240
52140	5260	5259	.1600
52141	5260	5257	.1600
52142	5256	5261	.1360
52143	5256	5251	.1360
52144	4637	5259	.1200
52145	5259	5256	.1240
52146	5257	5256	.1240
52159	5263	5257	.0210
52160	5263	5259	.0700

TABLE 4b
Radiation Conductor Data

Conductor Number	Coupled Nodes		Conductor Value (ft^2)
	i	j	
52127	5250	5261	.007
52128	5251	5252	.007
52129	5253	5254	.005
52130	5255	5256	.005
52147	5250	9999	.330
52148	5250	8888	.086
52149	5254	9999	.100
52150	5259	8888	.182
52151	5255	9999	.218
52152	5255	8888	.077
52153	5252	9999	.146
52154	5252	8888	.256
52155	5257	9999	.162
52156	5259	8888	.005
52157	5262	9999	.235
52158	5257	5262	.004

TABLE 5
Radiation Surface Data

Surface Number	Surface Finish	Optical Properties		
		Solar Absorptivity		Emissivity
		BOM	EOM	
5250	MLI	.40	.52	.72
5252	MLI	.40	.52	.72
5254	MLI	.40	.52	.72
5255	MLI	.40	.52	.72
5257	FST-8403	.16	.30	.78
5259	Irridite	---	---	.11
5262.1	MLI	.40	.52	.72
5262.2	MLI	.40	.52	.72

TABLE 6 SMM-TMM Nodal Correspondence	
Thermal Number	Surface Number
5250	5250
5252	5252
5254	5254
5255	5255
5257	5257
5259	5259
5262	5262.1
5262	5262.2

Appendix D

Electronics Results

Title	Case	Description			
		Scenario	Case	Condition	Radiator
1. Electronics	NM-H-O-P	Nominal	Hot	Operating	---
2. Electronics	NM-C-O-P	Nominal	Cold	Operating	---
3. Electronics	NM-H-N-P	Nominal	Hot	Non-operating	---
4. Electronics	NM-C-N-P	Nominal	Cold	Non-operating	---
5. Electronics	EM-H-N-P	Extended	Hot	Non-operating	PEI
6. Electronics	EM-H-N-O	Extended	Hot	Non-operating	OSR
7. Electronics	EM-H-N-G	Extended	Hot	Non-operating	Green
8. Electronics	PM-H-N-P	Pre-	Hot	Non-operating	PEI
9. Electronics	PM-H-N-O	Pre-	Hot	Non-operating	OSR
10. Electronics	PM-H-N-G	Pre-	Hot	Non-operating	Green

---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 14:19

Steady State Matrix Routine

1. Electronics
NM-H-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -8.850E-04 (C) ON NODE 5262
MAXIMUM NODAL ENERGY BALANCE = 3.024E-05 (W) ON NODE 5253
MAXIMUM SYSTEM ENERGY BALANCE = 1.127E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-127.049	Arith.	
5251	31.680	Arith.	
5252	-90.507	Arith.	
5253	37.133	Arith.	
5254	-89.430	Arith.	
5255	-120.918	Arith.	
5256	30.947	Arith.	
5257	27.314	Arith.	
5258	54.435	Arith.	3.220E+00
5259	34.701	Arith.	
5260	43.227	Arith.	3.910E+00
5261	31.651	Arith.	
5262	-165.723	Arith.	
5263	51.953	Arith.	1.725E+00
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	30.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

---

---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 14:41

Steady State Matrix Routine

2. Electronics
NM-C-O-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 8 ***

MAX. ARITH. NODE TEMP. CHANGE = -6.104E-05 (C) ON NODE 5251
MAXIMUM NODAL ENERGY BALANCE = -5.049E-05 (W) ON NODE 5259
MAXIMUM SYSTEM ENERGY BALANCE = -4.233E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-167.283	Arith.	
5251	-10.205	Arith.	
5252	-150.589	Arith.	
5253	-6.151	Arith.	
5254	-149.417	Arith.	
5255	-164.804	Arith.	
5256	-10.715	Arith.	
5257	-12.452	Arith.	
5258	6.638	Arith.	2.380E+00
5259	-9.117	Arith.	
5260	-3.347	Arith.	2.380E+00
5261	-10.210	Arith.	
5262	-179.941	Arith.	
5263	4.124	Arith.	1.275E+00
8888	-150.000	Bndry.	
9999	-273.000	Bndry.	
4637	-20.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------
---
---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 14:47

Steady State Matrix Routine

3. Electronics
NM-H-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 8 ***

MAX. ARITH. NODE TEMP. CHANGE = 3.052E-05 (C) ON NODE 5260
MAXIMUM NODAL ENERGY BALANCE = 3.840E-05 (W) ON NODE 5257
MAXIMUM SYSTEM ENERGY BALANCE = 5.212E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE
5250	-131.903	Arith.
5251	-5.356	Arith.
5252	-93.004	Arith.
5253	-5.419	Arith.
5254	-92.401	Arith.
5255	-125.114	Arith.
5256	-5.448	Arith.
5257	-9.593	Arith.
5258	-5.419	Arith.
5259	-.486	Arith.
5260	-5.040	Arith.
5261	-5.386	Arith.
5262	-178.918	Arith.
5263	-2.588	Arith.
8888	-75.000	Bndry.
9999	-273.000	Bndry.
4637	40.000	Bndry.

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 14:54

Steady State Matrix Routine

4. Electronics
NM-C-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 8 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.068E-04 (C) ON NODE 5257
MAXIMUM NODAL ENERGY BALANCE = -8.974E-06 (W) ON NODE 5261
MAXIMUM SYSTEM ENERGY BALANCE = -1.297E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-169.343	Arith.	
5251	-18.502	Arith.	2.550E+00
5252	-151.945	Arith.	
5253	-20.364	Arith.	
5254	-151.779	Arith.	
5255	-167.031	Arith.	
5256	-20.369	Arith.	
5257	-23.117	Arith.	
5258	-20.364	Arith.	
5259	-20.873	Arith.	
5260	-21.995	Arith.	
5261	-18.506	Arith.	2.550E+00
5262	-183.753	Arith.	
5263	-21.391	Arith.	
8888	-150.000	Bndry.	
9999	-273.000	Bndry.	
4637	-30.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------
---
---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 15:24

Steady State Matrix Routine

5. Electronics
EM-H-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -5.875E-04 (C) ON NODE 5262
MAXIMUM NODAL ENERGY BALANCE = -2.789E-05 (W) ON NODE 5257
MAXIMUM SYSTEM ENERGY BALANCE = 3.984E-06 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-127.254	Arith.	
5251	30.303	Arith.	
5252	-90.616	Arith.	
5253	30.192	Arith.	
5254	-89.995	Arith.	
5255	-121.021	Arith.	
5256	30.163	Arith.	
5257	30.479	Arith.	7.500E+00
5258	30.192	Arith.	
5259	31.252	Arith.	
5260	30.866	Arith.	
5261	30.273	Arith.	
5262	-164.591	Arith.	
5263	31.074	Arith.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

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---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 15:26

Steady State Matrix Routine

6. Electronics
EM-H-N-O

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.678E-03 (C) ON NODE 5262
MAXIMUM NODAL ENERGY BALANCE = 2.128E-05 (W) ON NODE 5257
MAXIMUM SYSTEM ENERGY BALANCE = 2.653E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-128.837	Arith.	
5251	19.218	Arith.	
5252	-91.445	Arith.	
5253	19.124	Arith.	
5254	-90.830	Arith.	
5255	-122.422	Arith.	
5256	19.094	Arith.	
5257	18.000	Arith.	5.000E+00
5258	19.124	Arith.	
5259	21.387	Arith.	
5260	19.694	Arith.	
5261	19.188	Arith.	
5262	-169.053	Arith.	
5263	20.606	Arith.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

---

---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 15:27

Steady State Matrix Routine

7. Electronics
EM-H-N-G

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. ARITH. NODE TEMP. CHANGE = -1.221E-04 (C) ON NODE 5251
MAXIMUM NODAL ENERGY BALANCE = 2.646E-05 (W) ON NODE 5251
MAXIMUM SYSTEM ENERGY BALANCE = 4.823E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-123.862	Arith.	
5251	51.607	Arith.	
5252	-88.788	Arith.	
5253	51.458	Arith.	
5254	-88.156	Arith.	
5255	-118.000	Arith.	
5256	51.429	Arith.	
5257	54.521	Arith.	1.280E+01
5258	51.458	Arith.	
5259	50.208	Arith.	
5260	52.365	Arith.	
5261	51.577	Arith.	
5262	-155.995	Arith.	
5263	51.204	Arith.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

****

8. Electronics
PM-H-N-P

*** CURRENT TIME = 7.2000E+03 (sec) ***

LOOP NO. = 4 LAST TIME STEP = 3.0000E+02 (sec)
MAX. DIFFN. NODE TEMP. CHANGE = 6.042E-03 (C) ON NODE 5259
MINIMUM NETWORK STABILITY = 1.5005E+02 (sec) ON NODE 5253

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-105.552	Diffn.	
5251	18.259	Diffn.	
5252	-83.241	Diffn.	
5253	18.204	Diffn.	
5254	-75.409	Diffn.	
5255	-91.916	Diffn.	
5256	18.222	Diffn.	
5257	15.843	Diffn.	3.100E+00
5258	18.319	Diffn.	
5259	21.006	Diffn.	
5260	20.924	Diffn.	
5261	18.242	Diffn.	
5262	-93.578	Diffn.	
5263	20.038	Diffn.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

---

---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 15:46

Steady State Matrix Routine

8. Electronics
PM-H-N-P

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 8 ***

MAX. DIFFN. NODE TEMP. CHANGE = 1.526E-04 (C) ON NODE 5251
MAXIMUM NODAL ENERGY BALANCE = 1.883E-05 (W) ON NODE 5256
MAXIMUM SYSTEM ENERGY BALANCE = 4.353E-06 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-130.023	Diffn.	
5251	10.282	Diffn.	
5252	-92.055	Diffn.	
5253	10.200	Diffn.	
5254	-91.445	Diffn.	
5255	-123.466	Diffn.	
5256	10.170	Diffn.	
5257	7.956	Diffn.	3.100E+00
5258	10.200	Diffn.	
5259	13.434	Diffn.	
5260	10.695	Diffn.	
5261	10.252	Diffn.	
5262	-172.644	Diffn.	
5263	12.170	Diffn.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

****

9. Electronics
PM-H-N-O

*** CURRENT TIME = 7.2000E+03 (sec) ***

LOOP NO. = 5 LAST TIME STEP = 3.0000E+02 (sec)
MAX. DIFFN. NODE TEMP. CHANGE = -4.150E-03 (C) ON NODE 5251
MINIMUM NETWORK STABILITY = 1.5006E+02 (sec) ON NODE 5253

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-105.624	Diffn.	
5251	16.704	Diffn.	
5252	-83.303	Diffn.	
5253	16.655	Diffn.	
5254	-75.458	Diffn.	
5255	-91.969	Diffn.	
5256	16.679	Diffn.	
5257	13.860	Diffn.	2.400E+00
5258	16.796	Diffn.	
5259	19.726	Diffn.	
5260	19.878	Diffn.	
5261	16.683	Diffn.	
5262	-93.640	Diffn.	
5263	18.649	Diffn.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

---

---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 15:53

Steady State Matrix Routine

9. Electronics
PM-H-N-O

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 8 ***

MAX. DIFFN. NODE TEMP. CHANGE = 6.104E-05 (C) ON NODE 5263
MAXIMUM NODAL ENERGY BALANCE = 2.799E-05 (W) ON NODE 5259
MAXIMUM SYSTEM ENERGY BALANCE = 3.956E-05 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-130.454	Diffn.	
5251	6.870	Diffn.	
5252	-92.274	Diffn.	
5253	6.792	Diffn.	
5254	-91.666	Diffn.	
5255	-123.845	Diffn.	
5256	6.763	Diffn.	
5257	4.124	Diffn.	2.400E+00
5258	6.792	Diffn.	
5259	10.397	Diffn.	
5260	7.260	Diffn.	
5261	6.840	Diffn.	
5262	-174.014	Diffn.	
5263	8.949	Diffn.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

****

10. Electronics
PM-H-N-G

*** CURRENT TIME = 7.2000E+03 (sec) ***

LOOP NO. = 4 LAST TIME STEP = 3.0000E+02 (sec)
MAX. DIFFN. NODE TEMP. CHANGE = -4.669E-03 (C) ON NODE 5256
MINIMUM NETWORK STABILITY = 1.5002E+02 (sec) ON NODE 5253

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-104.967	Diffn.	
5251	30.301	Diffn.	
5252	-82.733	Diffn.	
5253	30.190	Diffn.	
5254	-75.004	Diffn.	
5255	-91.483	Diffn.	
5256	30.141	Diffn.	
5257	31.152	Diffn.	8.600E+00
5258	30.118	Diffn.	
5259	30.894	Diffn.	
5260	29.051	Diffn.	
5261	30.278	Diffn.	
5262	-93.059	Diffn.	
5263	30.806	Diffn.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

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---------- mTAB*HEAT ANALYZER -------- RELEASE 4.0 ----------

---

---------- Matrix Software Inc. ----------

Date: 07-09-91
Time: 15:57

Steady State Matrix Routine

10. Electronics
PM-H-N-G

** SOLUTION CONVERGED **

*** NO. ITERATIONS = 7 ***

MAX. DIFFN. NODE TEMP. CHANGE = -3.601E-03 (C) ON NODE 5262
MAXIMUM NODAL ENERGY BALANCE = -2.780E-05 (W) ON NODE 5259
MAXIMUM SYSTEM ENERGY BALANCE = -7.894E-06 (W)

NODE NO.	TEMPERATURE (C)	NODE TYPE	HEAT LOAD (W)
5250	-126.552	Diffn.	
5251	34.957	Diffn.	
5252	-90.244	Diffn.	
5253	34.839	Diffn.	
5254	-89.620	Diffn.	
5255	-120.398	Diffn.	
5256	34.809	Diffn.	
5257	35.724	Diffn.	8.600E+00
5258	34.839	Diffn.	
5259	35.394	Diffn.	
5260	35.559	Diffn.	
5261	34.928	Diffn.	
5262	-162.716	Diffn.	
5263	35.470	Diffn.	
8888	-75.000	Bndry.	
9999	-273.000	Bndry.	
4637	40.000	Bndry.	

****

Appendix E

ICD Update

July 11, 1991

To: Jim Spann (MSFC)

From: Greg Dirks (SwRI)

Subject: UVI Instrument ICD Revisions

The following ICD tables need to be changed/updated as indicated in this letter.

Table 3.3-1 UVI Thermal Characteristics

Item	Operating (C and W)				Non-Operating (C and W)			
	Tmin	Tmax	Qmin	Qmax	Tmin	Tmax	Qmin	Qmax
Cam. Baseplate	0	40	0	0	-20	40	0	9
Cam. Opt. Bench	20	30	2	12	-25	40	0	0
Cam. Radiator	-75	-55	0	0	-100	30	0	0
Ele. Stack	-15	40	5	11	-25	40	0	6
Ele. Radiator	-15	30	0	0	-25	40	0	0

Table 3.3-3 UVI Exterior Surface Definition

Item	Surface	Area sq. in.	Type	IR Emis.	Alpha BOM	Alpha EOM
Camera	Sides	700	MLI	.72	.40	.52
	+Z Face	205	MLI	.72	.40	.52
	-Z Face	233	Dow 23	.32	.62	.62
	Radiator	28	FST-8403	.78	.16	.30
Electronics	Sides	273	MLI	.72	.40	.52
	+Z Face	33	MLI	.72	.40	.52
	-Z Face	61	Irridite	.11	.60	.60
	Radiator	28	FST-8403	.78	.16	.30

Table 3.3-4a UVI Exterior Mounting Thermal Interface							
				Temperature (C)			
				Operating		Non-Operating	
Unit	Filler	Contact Area (sq in)	Conduct-ance (W/C)	Tmin	Tmax	Tmin	Tmax
Camera	Isolators	6.7	.20	-20	30	-30	40
E-Box	Isolators	2.5	.12	-20	30	-30	40

Table 3.3-4b UVI Exterior Mounting Conductive Limits					
		Heat Flow Limits (W)			
		Operating		Non-Operating	
Unit	Item	Cold	Hot	Cold	Hot
Camera	Isolator	-6/+3	-6/+3	-4/+4	-4/+4
E-Box	Isolator	-2/+2	-2/+2	-3/+5	-3/+5

Table 3.3-8 UVI Heater Circuits						
				Individual Heater Elements		
Circuit	Type	Control Method	Set-Point (C)	Number	Power (W)	Location
28 V Pulse	Operational	Analog/ Proportional	20 on 30 off	4	2.5	Camera Bench
28 V	Survival	Thermostat	-10	3	3.0	Cam. Base
28 V	Survival	Thermostat	-14	2	3.0	Ele. Sides

Table 3.3-2, UVI Exterior Surface Thermal Environment, has not been updated. This table is meant to be used in the preliminary design phase of which the UVI instrument is well past. Therefore, I recommend either deleting it entirely or leaving it as is.

The only change to the text should be to delete note 1 under table 3.3-1 on page 46.

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16. Abstract

The thermal analysis of the Ultraviolet Imager (UVI) camera and electronics has been completed. This analysis includes updated reduced thermal models (RTM's) that incorporate several design changes. New values for the Interface Control Document (ICD) have been proposed. The results of the analysis indicate that temperature limits for all mission scenarios will be within the proposed ICD values.

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